Simulating grid schedulers with deadlines and co-allocation

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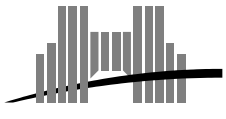

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Abstract

One of the true challenges in resource management in grids is to provide support for co-allocation, that is, the allocation of resources in multiples autonomous subsystems of a grid to single jobs. With reservation-based local schedulers, a grid scheduler can reserve processors with these schedulers to achieve simultaneous processor availability. However, with queuing-based local schedulers, it is much more difficult to guarantee this. In this paper we present mechanisms and policies for working around the lack of reservation mechanisms for jobs with deadlines that require co-allocation, and simulations of these mechanisms and policies.

Keywords: Grid, Scheduling, Simulation

Résumé

Un des véritables défis pour la gestion des ressources dans les environnements de type grilles est de fournir un support pour la co-allocation. La co-allocation est l'allocation des ressources dans des sous-systèmes autonomes et différents pour des tâches uniques. Aves des ordonnanceurs locaux à base de réservation, un ordonnanceur de grille peut faire appel à ces derniers pour réserver des processeurs afin d'utiliser efficacement les processeurs disponibles. Cependant, avec des ordonnanceurs locaux à base de système *batch*, il est beaucoup plus difficile de garantir une utilisation efficace des processeurs. Dans cet article nous proposons des mécanismes et des politiques pour palier au manque de mécanismes de réservation avec une date limite que requiert la co-allocation. Nous avons réalisé des simulations afin de valider ces mécanismes.

Mots-clés: Grille, Ordonnancement, Simulation

1 Introduction

Over the past years, multi-cluster systems consisting of several to several tens of clusters containing a total of hundreds to thousands of CPUs connected through a wide area network (WAN) have become available. Examples of such systems are the French Grid5000 system [3] and the Dutch Distributed ASCI Supercomputer (DAS)[5]. One of the challenges in resource management in such systems is to allow the jobs access to resources (processors, memory, etc.) in multiple locations simultaneously—so-called *co-allocation*. In order to use co-allocation, users submit jobs that consist of a set of *components*, each of which has to run on a single cluster. The principle of co-allocation is that the components of a single job have to start at the same time.

Co-allocation has already been studied with simulations and has been proven as a viable option in previous studies [2, 6]. A well-known implementation of a co-allocation mechanism is DUROC [4], which is also used in the KOALA scheduler. KOALA is a processor and data co-allocator developed for the DAS system [8, 7] that adds fault tolerance and scheduling policies to DUROC, and support for a range of job types.

One of the main difficulties of processor co-allocation is to have processors available in multiple clusters with autonomous schedulers at the same time. When such schedulers support (advance) reservations, a grid scheduler can try to reserve the same time slot with each of these schedulers. However, with queuing-based local schedulers such as SGE (now called SUN N1 Grid Engine) [9], which is used in the DAS, this is of course not possible. Therefore, we have designed and implemented in KOALA, which has been released in the DAS for general use in september 2005 (`www.st.ewi.tudelft.nl/koala`), mechanisms and policies for placing jobs (i.e., finding suitable executions sites for jobs) and for claiming processors before jobs are supposed to start in order to guarantee processor availability at their start time.

In this paper we present a simulation study of these mechanisms and policies where we assume that jobs that require co-allocation have a (starting) *deadline* attached to them. In Section 2, we describe the model we use for the simulations, and in Section 3 we discuss and analyse the results of these simulations. Finally, in Section 4 we conclude and introduce future work.

2 The Model

In this section we describe the system and scheduling model to be used in our simulations. Our goal is to test different policies of grid schedulers with co-allocation and deadlines. With co-allocation, jobs may consist of separate components, each of which requires a certain number of processors in a single cluster. It is up to the grid scheduler to assign the components to the clusters. Deadlines allow a user to specify a precise job start time; when the job cannot be started at that time, its results will be useless or the system may just give up trying to schedule the job and leave it to the user to re-submit it.

One of the main problems of co-allocation is to ensure that all job components will be

started at a specified time simultaneously. In queuing-based systems, there is no guarantee that the required processors will be free at a given time. On the other hand, busy processors may be freed on demand in order to accommodate a co-allocated (or *global*) job that has reached its deadline. Therefore, we assume that the possibility exists to kill jobs that do not require co-allocation (*local jobs*). In our model, the global jobs have deadlines at which they should start, otherwise they will be considered as failed.

As an alternative to this model (or rather, to the interpretation of deadlines), one may consider jobs with components that have input files which first have to be moved to the locations where the components will run. When these locations have been fixed, we may estimate the file transfer times, and set the start time of a job as the time of fixing these locations plus the maximum transfer time. Then this start time can play the same role as a real deadline. The difference is that in our model, if the deadline is not met, the job fails, while in this alternative, the job may still be allowed to start, possibly at different locations.

2.1 System model

We assume a multicluster environment with C clusters, which for the sake of simplicity is considered to be homogeneous (*e.g.*, every processor has the same power). We also assume in our simulations that all cluster are of identical size, which we denote by N the number of nodes. Each cluster has a local scheduler that applies the First Come First Served (FCFS) policy to single-component local jobs sent by the local users. The scheduler can kill those local jobs if needed. When they arrive, the new jobs requiring co-allocation are sent to a single global queue called the *placement queue*, and here the jobs wait to be assigned to some clusters.

In our model we only consider unordered jobs, which means that the execution sites of a job are not specified by the user, but that the scheduler must choose them. A Poisson arrival process is used for the jobs requiring co-allocation and for the single-component jobs for each cluster, with arrival rates λ_g for global jobs and λ_l for the local ones in each cluster.

A job consists of a number of components that have to start simultaneously. The number of components in a multi-component job is generated from the uniform distribution on $[2, C]$. The number of components can be 1 only for local jobs which do not require co-allocation. The deadline for a job (or rather the time between its submission and its required start time) is also chosen randomly with a uniform distribution on $[D_{min}, D_{max}]$, for some D_{min} and D_{max}. The number of processors needed by a component is taken from the interval $I_s = [4, S]$, where S is the size of the smallest cluster. Each component of a job will require the same number of processors. Two methods are used to generate that size. The first is the uniform distribution on I_s. The second, which we have used in previous simulation work in order to have more sizes that are power of two as well as more small sizes, is more realistic [2]. In this distribution, which we call the Realistic Synthetic Distribution, a job component has a probability of q^i/Q to be of size i if i is not a power of two, and $3q^i/Q$ to be of size i if i is a power of two. Here $0 < q < 1$, and the value of Q

is chosen to make the sum of the probabilities equal to 1. The factor 3 is made to increase the probability to have a size that is a power of 2 and q^i to increase the chance to have a small size.

Finally, the computation time of the job has an exponential distribution with parameter μ_g for the global jobs and μ_l for the local jobs.

2.2 Scheduling Policies

In this section the so-called *Repeated Placement Policy* (RPP) will be described. Variations of this policy are used in the KOALA scheduler both for placing jobs and for claiming processors.

Suppose a co-allocated job with deadline D is submitted at time S. The RPP has a parameter L_p, $0 < L_p < 1$, which is used in the following way. The first placement try will be at time PT_0, with:

$$PT_0 = S + L_p \cdot (D - S).$$

If placement does not succeed at PT_m, the next try will be at PT_{m+1}, defined as:

$$PT_{m+1} = PT_m + L_p \cdot (D - PT_m).$$

As this policy can be applied forever, a limit on m has to be set, which will be denoted M_p. If the job is not placed at PT_M, it is considered as failed. When a placement try is successful, the processors allocated to the job are claimed immediately. Note that with this policy, the global jobs are not necessarily scheduled in FCFS order.

In our simulations, the Worst Fit placement policy is used for job placement, which means that the components are placed on the clusters with the most idle processors. With this method, a sort of load balancing is performed. We assume that different components of the same job can be placed on the same cluster.

If the deadline of a newly submitted multi-component job is very far away in the future, it may be preferable to wait until a certain time before considering the job. The scheduler will simply ignore the job until $T = D - I$, where D is the deadline and I is the *Ignore* parameter of the scheduler. We will denote by Wait-X the policy with $I = X$. With set I to ∞, no job will ever be ignored. In our model, there are is a single global queue for the multi-components jobs, and a local queue for each cluster for single-component jobs. In order to give global or local jobs priority, we define the following policies [1]:

GP: When a global job has reached its deadline and not sufficient processors are idle, local jobs are killed.

LP: When we cannot claim sufficient numbers of processors for a global multi-component job, that job fails.

2.3 Performance metrics

In order to assess the performances of the different scheduling policies, we will use the following metrics:

The global job success rate: The percentage of co-allocated jobs that were started successfully at their deadline.

The local job kill rate: The percentage of local jobs that have been killed.

The total load: The average percentage of busy processors over the entire system.

The global load: The percentage of the total computing power that is used for computing the global jobs. It represents the effective computing power that the scheduler has been able to get from the grid.

The processor wasted time: The percentage of the total computing power that is wasted because of claiming processors before the actual deadlines of jobs.

3 Simulations

In this section we present our simulation results. We first discuss the parameters of the simulation, then we simulate the *pure* Repeated Placing Policy, which does not ignore jobs, and finally discuss the Wait-X policies.

3.1 Setting the parameters

All our simulations are for a multicluster system consisting of 4 clusters of 32 processors each, and unless specified otherwise, the GP policy is used. The number of processors needed by a local job (its size) is denoted S_l and is generated on the interval $[1; 32]$ with the Realistic Synthetic Distribution with parameter $q = 0.9$. The expected value of S_l is $E[S_l] = 6.95$.

We set $\mu_l = 0.01$ so that local jobs have an average runtime of 100 seconds. Then the (requested) local load U_l in every cluster due to local jobs is equal to:

$$U_l = \frac{\lambda_l \cdot E[S_l]}{\mu_l \cdot N}.$$

We run simulations with a *low local load* of 30% and a *high local load* of 60%.

We denote by S_g the size of a component of a global job, which is taken on the interval $[4; 32]$ and which is also generated using the Realistic Synthetic Distribution with parameter $q = 0.9$. The expected value of S_g is $E[S_g] = 10.44$. The number of components of a global job, N_c, is taken uniformally on the interval $[2; 4]$. In our simulations we set $\mu_g = 0.005$,

so the global jobs have an average runtime of 200 seconds. The (requested) global load, denoted U_g, is given by:

$$U_g = \frac{\lambda_g \cdot E[N_c] \cdot E[S_g]}{\mu_g \cdot N \cdot C}.$$

It should be noted that we cannot compute the actual (local or global) load in the system. The reasons are that local jobs may be killed, there is processor wasted time because we claim processors early, and global jobs may fail because they don't meet their deadlines. However, the useful load can be computed.

We run simulations with a *low global load* of 20% and a a *high global load* of 40%. The results of a first general simulation, with $L_p = 0.7$, are shown in Figure 1.

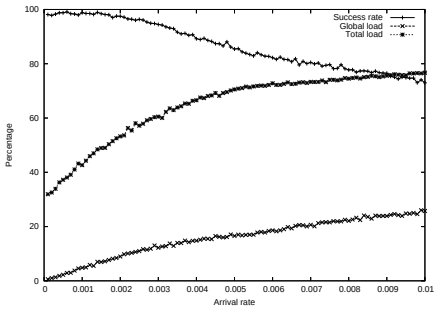


Figure 1: Some metrics as a function of the arrival rate of global jobs with a low local load (30%).

3.2 The Pure Repeated Placing Policy

In this section we study the influence of the parameters of the Repeated Placing Policy, which is nothing else than the Wait-∞ policy. The deadline is chosen uniformally on the interval $[1; 3599]$. The parameter we vary is L_p.

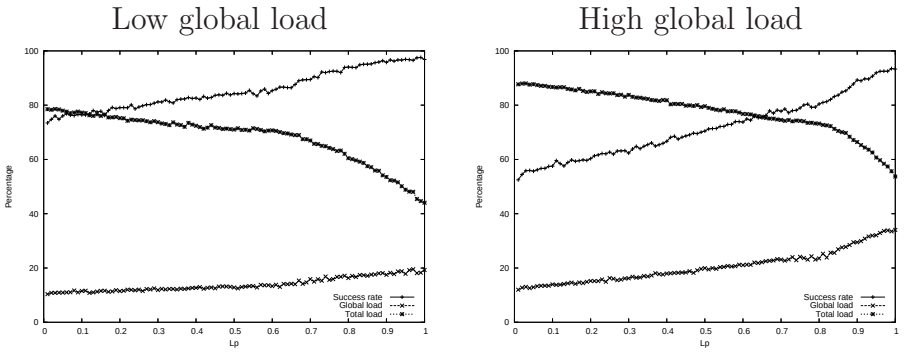


Figure 2: The influence of L_p with a low local load.

We first study the Wait-∞ policy with a low local load. We expected that the success rate of global jobs will be higher for lower values of L_p, but this is not the case, as shown in Figure 2 for a low local load. These results may seem strange because RPP is designed to have a high success rate for global jobs. The processors for the global jobs are claimed earlier in order to ensure that their availability at the deadlines. In fact, the first jobs have indeed a greater success rate but the ones that come after them find fewer free processors, what causes them to fail. This analysis is clear when analysing the total load as a function of L_p. It seems preferable to set L_p to 1 with any arrival rate of the global jobs, at least for a low local load. However, the conclusion may be different with a high local load.

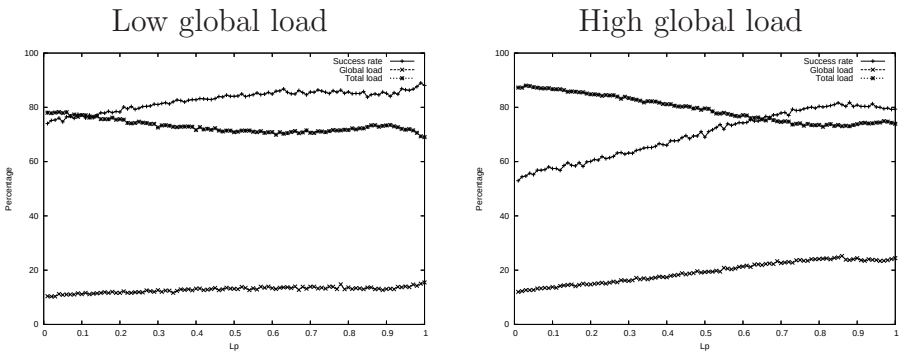


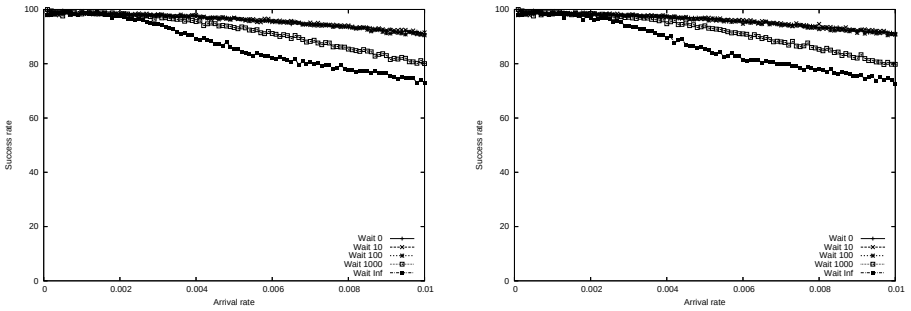
Figure 3: The influence of L_p with a high local load.

Therefore, we study the influence of L_p with a high local load (60%). The results of those simulations shown in Figures 3 are very similar to the ones with a low local load. The success rate decreases a little bit when L_p is close to 1 when both the local and global loads are high, which is due to the fact that the total requested load is equal to 100%. This leads to the conclusion that the best way to meet the deadlines is simply to try to run the jobs at their starting deadlines with the hope that there will be enough free processors.

3.3 The Wait-X Policies

We have shown that the pure RPP (Wait-∞) is not efficient since a value of L_p close to 1 is the best setting, which causes much processor time to be wasted. However, as described in Section 2.2, it might be preferable to simply ignore jobs until I seconds before their starting deadline. Since the scheduling policy may affect the results, we study both LP and GP policies. In this section we fix L_p at 0.7.

According to the results shown in Figure 4, ignoring the jobs until 100 seconds or less before their starting deadline gives more or less the same results, while a pure RPP and ignoring until 1000 seconds before the deadline gives less good results. The Wait-0, Wait-10, and Wait-100 policies seem to be the most suitable choices for any arrival rate of the global jobs. We will prefer the Wait-10 policy to the two others because we want to have the possibility to place a job again in the case of failure, what we cannot do with the Wait-0

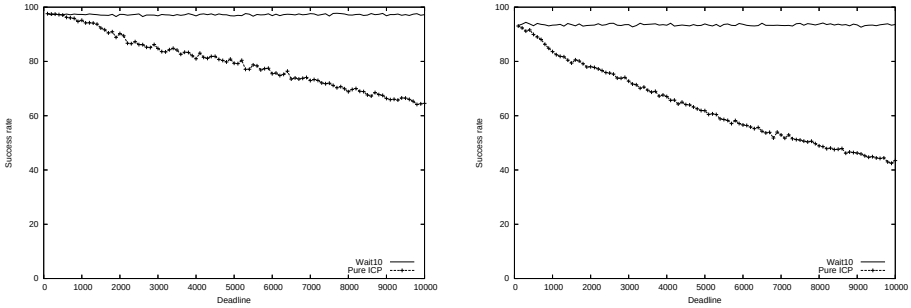


GP LP

Figure 4: Comparison of different ignoring policies with a low local load varying the global arrival rate λ_g.

policy. We also do not want to have the overhead of applying the RPP over a too large interval of time.

The next parameter we investigated the influence of is the deadline (that is, the time between submission and required start time) of global jobs. Since the Wait-10 policy was concluded to be the most suitable scheduling policy we compare it to the pure RPP. We compare the success rates of the global jobs depending on their deadline. The results are in Figures 5 and 6. As expected, in both cases, the behavior of the Wait-10 scheduling policy is not affected by the value of the deadline, and the Wait-10 policy has better results than the pure RPP policy for any global load.

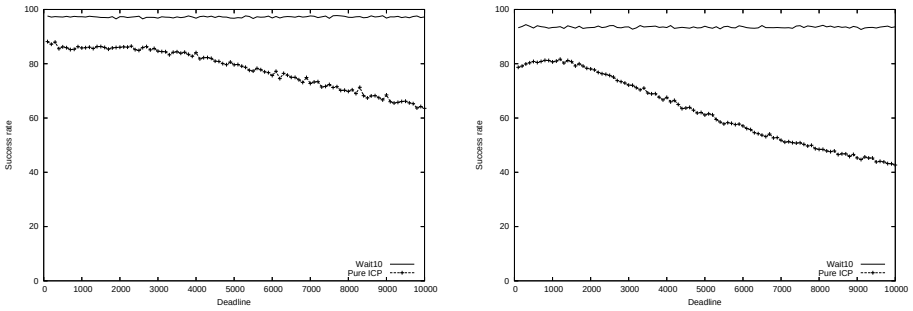


Low global load High global load

Figure 5: The influence of the deadline with a low local load.

We now study the influence of the load due to the single-component local jobs on both the RPP and the Wait-10 policies. The GP scheduling policy is used because, with high local loads, the global jobs may not be able to run with the LP policy. As shown in Figure 7, the Wait-10 and pure RPP policies have rather the same success rate while varying the local load.

Finally, we trace the impact of the different scheduling policies on the local jobs. The



Low global load High global load

Figure 6: The influence of the deadline with a high local load.

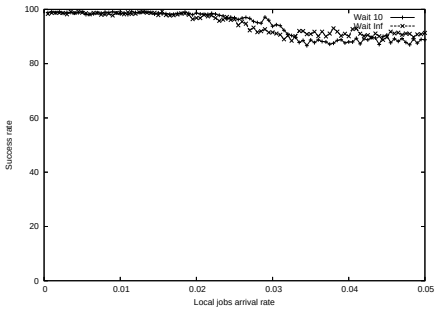


Figure 7: The influence of the local load on the Wait-10 and pure RPP policies with a low global load.

policy will always be GP because a LP policy may not influence the local jobs. As we can see in Figure 8, the pure RPP does not let the local jobs run properly while the other policies are much nicer with them, with also better results for the global jobs as we have shown previously. The results shown in Figure 9 are also in favor of the Wait-10 policy because when I is set to great values such as 1000 or ∞ there is a considerable amount of local jobs that are killed.

4 Conclusions

In this paper we have presented a simulation study of grid schedulers with deadlines and co-allocation based on queuing-based local schedulers. We have shown that it is better to start considering jobs a short period of time before their deadline of global jobs. Considering the jobs too early may cause many jobs to fail; the first jobs, indeed, run fine but waste a lot of processor time, while the next ones do not have enough processors to run.

An extension to this work could be to consider the communication overheads that happen on real grids. The Wait-10 policy which was concluded as the best policy may not

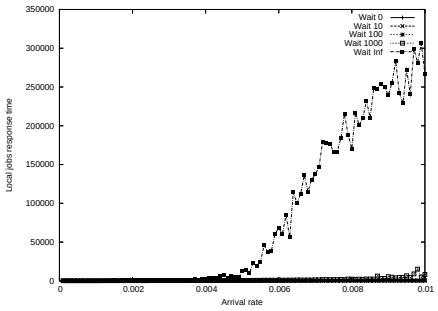


Figure 8: The response time of local jobs as a function of the arrival rate of global jobs with different scheduling policies with a low local load.

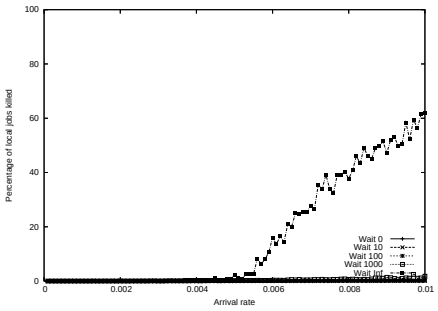


Figure 9: The percentage of local jobs killed as a function of the global jobs arrival rate with different scheduling policies with a low local load.

be that good and the best value for I may depend on these overheads. We may also extend this work by considering the parameter I as a priority parameter. It may be interesting to consider the higher prioriy jobs earlier than the lower priority ones in order to ensure that the high priority jobs will run even if they waste a lot of processor time.

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